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APPLICATION TRANSMITTAL**(Only for new nonprovisional applications
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Docket No.**991527**Total
Pages

First Named Inventor or Application Identifier

**Katsumi MIYATA, Eiji WATANABE
and Hiroyuki YODA**

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APPLICATION ELEMENTS FOR:

**SEMICONDUCTOR DEVICE AND METHOD OF
MANUFACTURING THE SAME**ADDRESS TO: Assistant Commissioner for Patents
BOX PATENT APPLICATIONS
Washington, D.C. 20231

1. ☒ Fee Transmittal Form (Incorporated within this form)
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2. ☒ Specification Total Pages **[29]**
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4. ☒ Oath or Declaration Total Pages **[5]**
 - a. ☒ Newly executed (original)
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ACCOMPANYING APPLICATION PARTS

8. ☒ Assignment Papers (cover sheet and document(s))
9. ☐ 37 CFR 3.73(b) Statement (when there is an assignee) ☒ Power of Attorney

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PAGE 2 OF 3

10. ☐ English translation Document (if applicable)

11. ☒ Information Disclosure Statement ☐ [1] Copies of IDS Citations

12. ☐ Preliminary Amendment

13. ☒ Return Receipt Postcard (MPEP 503)

14. ☐ Small Entity Statement(s) ☐ Statement filed in prior application
Status still proper and desired.

15. ☒ Claim for Convention Priority ☐ [1] Certified copy of Priority Document(s)

- a. Priority of _____ application no's. _____ filed on _____ is claimed under 35 USC 119. The
certified copies/copy have/has been filed in prior application Serial No. _____.
(For Continuing Applications, if applicable).

16. ☐ Other _____

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:

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FEE TRANSMITTAL	Number Filed	Number Extra	Rate	Basic Fee
The filing fee is calculated below				\$690.00
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Independent Claims	3-3	0	x \$78.00	
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Reduction by ½ for small entity				
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TOTAL				730.00

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18. **CORRESPONDENCE ADDRESS**

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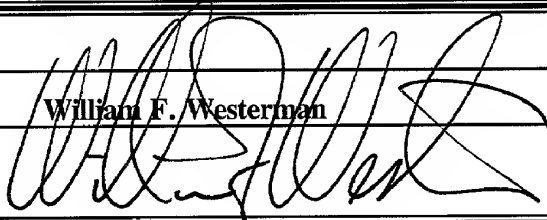
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Reg. No. **29,988**

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Date: **January 6, 2000**

WFW/llf

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, Katsumi Miyata, a citizen of Japan residing at Aizuwakamatsu-shi, Fukushima, Japan, Eiji Watanabe, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan and Hiroyuki Yoda, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan have invented certain new and useful improvements in

SEMICONDUCTOR DEVICE AND METHOD OF MANUFACTURING THE SAME

of which the following is a specification : -

TITLE OF THE INVENTION

SEMICONDUCTOR DEVICE AND METHOD OF
MANUFACTURING THE SAME

5 BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to a semiconductor device and a method of manufacturing the same. The present invention particularly relates to a method of manufacturing a semiconductor device provided with electrodes formed on a semiconductor substrate, barrier metals formed on respective electrodes and protruded electrodes joined to the electrodes via the barrier metals.

15 Recently, there is a decrease in the sizes of semiconductor devices. It is known to use protruded electrodes such as bumps as external connection terminals of the miniaturized semiconductor devices. The semiconductor devices having protruded electrodes may be a BGA (Ball Grid Array) type semiconductor device or a CSP (Chip Size Package) type semiconductor device.

Also, the semiconductor devices require higher reliability, and thus, it is necessary that protruded electrodes also realize higher reliability.

25 2. Description of the Related Art

Fig. 1 is a side view of an example of a semiconductor device of a related art having bumps and electrode pads. Here, Fig. 1 shows a semiconductor device 1 of a general CSP type. As shown in Fig. 1, the semiconductor device 1 has a plurality of electrode pads 3 provided on a circuit forming surface 2a of the semiconductor chip 2. Each electrode pad 3 is provided with a bump 4 which serves as an external connection terminal.

35 Fig. 2 is an enlarged view showing a region around the electrode pad 3 provided on the semiconductor device 1 of Fig. 1. The electrode pad

3 includes an electrode 5 and a barrier metal 10. As shown in Fig. 2, the bump 4 is not directly formed on the electrode 5, but is joined to the electrode 5 via the barrier metal 10 provided on the electrode 5. The detailed structure of the semiconductor device 1 will be described below.

The circuit forming surface 2a of the semiconductor chip 2 is provided with an insulating layer 6 for protecting the circuit forming surface 2a. The insulating layer 6 is provided with openings 7 at positions corresponding to the electrodes 5 such that the electrodes 5 are exposed via the openings 7.

The barrier metal 10 has a layered structure of a first conductive metal layer 11, a second conductive metal layer 12, and a third conductive metal layer 13. The barrier metal 10 prevents the bump 4 from diffusing into the electrode 5. For example, when the bump 4 is made of solder and a gold (Au) plating is applied on the electrode 5, and if the bump 4 is directly joined to the electrode 5, the solder will diffuse into the gold plating of the electrode 5. This causes a decrease in strength of the diffused part, which may result in the peeling off of the bump 4 from the electrode 5. The barrier metal 10 prevents the bump 4 from diffusing into the electrode 5 and thus prevents the bump 4 from being peeled off from the electrode 5.

The first conductive metal layer 11 is provided at a position nearest to the semiconductor chip 2 or at the lowermost position. This first conductive metal layer 11 is made of a material having a good joining property with the electrode 5. The second conductive metal layer 12 is provided on the first conductive metal layer 11. This second conductive metal layer 12 is made of a material having a good joining property with the first conductive metal layer 11. The third conductive metal layer 13 is

provided on the second conductive metal layer 12. This third conductive metal layer 13 is made of a material having a good joining property with the second conductive metal layer 12 and the bump 4. Also, the
5 third conductive metal layer 13 should be made of a material which can prevent the diffusion of the bump 4.

The semiconductor device 1 is manufactured in the following manner. First, the barrier metals 10
10 are formed. In order to manufacture the barrier metal 10, the first conductive metal layer 11 is formed on the semiconductor chip 2 such that the first conductive metal layer 11 is electrically connected to the electrode 5. Then, the second conductive metal layer
15 12 is laminated on the first conductive metal layer 11. Subsequently, a resist having openings corresponding to predetermined shapes of the barrier metals is formed on the second conductive metal layer 12. With this resist being provided on the second
20 conductive metal layer, the third conductive metal layer 13 is formed. Thereafter, the resist is removed. Further, unwanted parts of the first and second conductive metal layers 11 and 12 are removed by etching. Thus, the barrier metal 10 is obtained.

25 The bumps 4 serving as external connection terminals are formed by transferring solder balls onto the barrier metals 10 and heating the solder balls so that the solder balls will be joined to the barrier metals 10.

30 After the bumps 4 have been formed as described above, a testing step is carried out. As shown in Fig. 3, probes 14 connected to a tester or a testing device (not shown) are brought in contact with the bumps 4. This may be referred to as "probing".
35 Then, test signals from the tester are supplied to the semiconductor chip 2 via the probes 4. Thus, a predetermined test such as a reliability test or an

operational test can be implemented on the semiconductor chip 2. Thereby, good semiconductor devices are selected.

With the method of manufacturing the semiconductor device of the related art, the testing step is carried out after the bumps 4 have been formed on the barrier metals 10. Therefore, the probes 14 should be connected to the bump 4. However, it is difficult to properly connect the probe 14 to the bump 4 having a spherical shape. Also, according to the recent miniaturization of the semiconductor device 1, further fine-pitched structures, such as an area array, have been introduced. Then, there arises a problem that it is even more difficult to properly connect the probe 14 to the bump 4 having a spherical shape.

Also, when the probe 14 is directly probed on the bump 4, the material of the bump 4 will adhere to the tip part of the probe 14. Examples of the material forming the bump 4 may be tin (Sn) or lead (Pb). On the other hand, generally, the tip part of the probe 14 is provided with a plated part 15. For example, when the probe 14 is made of palladium (Pd), the plated part 15 may be of gold.

It is well known that tin reacts with gold. Therefore, if the material of the bump 4 adheres onto the tip part of the probe 14, the probe 14 will be degraded over a several usage. This results in a drawback that the reliability of the testing step is reduced. Also, there is a drawback that the testing cost increases since a frequent replacement of the costly probes 14 is necessary.

SUMMARY OF THE INVENTION

Accordingly, it is a general object of the present invention to provide a method and a device of manufacturing a semiconductor device which can overcome the drawbacks described above.

It is another and more specific object of the present invention to provide method and a device of manufacturing a semiconductor device which can improve the reliability of the testing step while reducing the
5 cost of the testing step.

In order to achieve the above objects according to the present invention, a method of manufacturing a semiconductor device includes the steps of:

- 10 a) forming barrier metals on first electrodes provided on a chip of the semiconductor device;
- b) implementing, after the step a), a predetermined test on the semiconductor device by
15 applying a signal to the semiconductor device via at least one of the barrier metals; and
- c) forming, after the step a), second protruded electrodes on the barrier metals.

With the method described above, connection
20 terminals (e.g., probes) for testing used in the testing step are not connected to the spherical protruded electrodes but connected to the barrier metal having substantially flat surfaces. Therefore, the connection terminals for testing can be securely
25 connected to the barrier metals.

It is still another object of the present invention to provide method and a device of manufacturing a semiconductor device which can reduce the cost of the testing step while improving the
30 reliability of the testing step. Thereby, reliability test such as an electric test and a burn-in test can be implemented with a high reliability.

In order to achieve the above object, the step a) includes a step of forming the barrier
35 metals each having a multilayer structure having uppermost conductive metal layer which is made of a material which can be alloyed with a material of the

second protruded electrodes and has a resistance to reaction and adhesion with a material of probes used for the step b) and with a material of plated parts provided on the probes.

5 With the above structure, the reliability of the test can be improved and there is no need for a frequent replacement of costly probes.

 Other objects and further features of the present invention will be apparent from the following
10 detailed description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

 Fig. 1 is a side view of an example of a
15 semiconductor device of a related art having bumps and electrode pads.

 Fig. 2 is an enlarged view showing a region around the electrode pad provided on the semiconductor device of Fig. 1.

20 Fig. 3 is diagram showing a testing step carried out in a method of manufacturing a semiconductor device of the related art.

 Figs. 4 to 9 are diagrams showing various sub-steps of a barrier metal forming step of a first
25 embodiment of a method of manufacturing a semiconductor device of the present invention.

 Fig. 10 is a diagram showing an individualized semiconductor chip provided with barrier metals.

30 Figs. 11 and 12 are diagrams showing how the electrical test is carried out on the semiconductor chip.

 Fig. 13 is a diagram showing how the burn-in test is carried out on the semiconductor chip.

35 Fig. 14 is an enlarged view showing a region around the electrode pad provided on the semiconductor device of a first embodiment of the present invention.

Fig. 15 is a chart showing combinations of materials of the probe and the third conductive metal layer and possible materials of the fourth conductive metal layer.

5 Figs. 16 to 19 are diagrams showing various barrier metal forming steps of a second embodiment of a method of manufacturing a semiconductor device of the present invention.

10 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following, principles and embodiments of the present invention will be described with reference to the accompanying drawings.

15 Figs. 4 to 15 are diagrams illustrating a manufacturing method of a semiconductor device 20 of a first embodiment of the present invention. In Figs. 4 to 9, components similar to those shown in Figs. 1 to 3 are indicated with similar reference numerals.

20 First of all, for the sake of convenience, a structure of the semiconductor device 20 to be manufactured will be described in detail. Fig. 14 is an enlarged view showing a region around an electrode pad 23 provided on the semiconductor device 20 of a first embodiment of the present invention.

25 Referring to Fig. 14, the electrode pad 23 provided on the semiconductor device 20 includes an electrode 5 formed on a semiconductor chip 27 and a barrier metal 30A formed on the electrode 5. The barrier metal 30A provided on the semiconductor device 30 20 of the present embodiment has a layered structure of a first conductive metal layer 31, a second conductive metal layer 32, a third conductive metal layer 33 and a fourth conductive metal layer 34.

35 The first conductive metal layer 31 is layered at a position nearest to the semiconductor chip 2 so as to be joined to the electrode 5. The first conductive metal layer 31 may also be referred to as

a lowermost conductive metal layer. This first conductive metal layer 31 is made of a material having a good joining property with the electrode 5. In the present embodiment, the first conductive metal layer 31 is made of a material such as titanium (Ti) and has a thickness of about 500 nm.

Instead of titanium, the first conductive metal layer 31 may be made of a metal chosen from a group consisting of chromium (Cr), molybdenum (Mo) and tungsten (W), or of an alloy containing a metal chosen from a group consisting of titanium (Ti), chromium (Cr), molybdenum (Mo) and tungsten (W).

The second conductive metal layer 32 is interposed between the first conductive metal layer 31 and the third conductive metal layer 33. This second conductive metal layer 32 is made of a material having a good joining property with both the first conductive metal layer 31 and the third conductive metal layer 33. In the present embodiment, the second conductive metal layer 32 is made of a material such as nickel (Ni) and has a thickness of about 500 nm.

Instead of nickel, the second conductive metal layer 32 may be made of a metal chosen from a group consisting of copper (Cu) and palladium (Pd), or of an alloy containing a metal chosen from a group consisting of copper (Cu), nickel (Ni) and palladium (Pd).

The third conductive metal layer 33 is interposed between the second conductive metal layer 32 and the fourth conductive metal layer 34. This third conductive metal layer 33 is made of a material having a good joining property with both the second conductive metal layer 32 and the fourth conductive metal layer 34. In the present embodiment, the third conductive metal layer 33 is made of a material such as copper (Cu) and has a thickness of about 500 nm.

Instead of copper, the third conductive

metal layer 33 may be made of a metal chosen from a group consisting of nickel (Ni) and palladium (Pd), or of an alloy containing a metal chosen from a group consisting of copper (Cu), nickel (Ni) and palladium (Pd).

The second conductive metal layer 32 and the third conductive metal layer 33 are interposed between the first conductive metal layer 31 (lowermost conductive layer) and the fourth conductive metal layer 34. Thus, a combination of the second conductive metal layer 32 and the third conductive metal layer 33 may also be referred to as an intermediate conductive layer.

The fourth conductive metal layer 34 is layered at a position distal from the semiconductor chip 2. The fourth conductive metal layer 34 may also be referred to as an uppermost conductive metal layer. This fourth conductive metal layer 34 is made of a material which can be easily alloyed with the material of a bump 35 and which has resistance to oxidation. In the present embodiment, the material of the bump 35 is solder. Also, the fourth conductive metal layer 34 is made of a material such as gold (Au) and has a thickness of about 0.1 μm .

Instead of gold, the fourth conductive metal layer 34 may be made of a metal chosen from a group consisting of platinum (Pt), palladium (Pd), silver (Ag) and rhodium (Rh) or of an alloy containing a metal chosen from a group consisting of gold (Au), platinum (Pt), palladium (Pd), silver (Ag) and rhodium (Rh).

In the above described structure, each one of the first to fourth conductive metal layers 31 to 34 are described as a single metal layer. However, each one of the first to fourth conductive metal layers 31 to 34 may also have a layered structure of a plurality of conductive metal layers.

The bump 35 is an example of a protruded

electrode. It is to be note that the protruded electrode is not limited to a spherical ball but can also take other shapes such as a stud bump. In the present embodiment, the bump 35 serves as an external terminal and has a substantially spherical shape. Considering a secure mounting of the semiconductor device 20, the bump 35 is made of a material chosen so as to improve joining property with the mounting substrate. Thus, in the present embodiment, the bump 35 is made of solder which is an alloy of tin (Sn) and lead (Pb). For example, a solder having a Pb/Sn ratio of 95%/5% is used. The bump 35 may have a height of about 100 μ m.

Instead of solder, the bump 35 may be made of a metal chosen from a group consisting of tin (Sn), lead (Pb), silver (Ag), indium (In) and bismuth (Bi) or of an alloy containing a metal chosen from a group consisting of tin (Sn), lead (Pb), silver (Ag), indium (In) and bismuth (Bi). Any of the metals and alloys may be selected, as long as the selected metal or alloy has a low melting point of less than or equal to about 350 $^{\circ}$ C.

In the present embodiment, the fourth conductive metal layer 34 is made of gold (Au) which can be easily alloyed with solder used as a material of the bump 35. Thus, a metal having a good joining property with the bump 35 may be selected as a material of the fourth conductive metal layer 34, so as to improve the joining property between the fourth conductive metal layer 34 and the bump 35.

Also, the fourth conductive metal layer 34 is made of a material having a good resistance to oxidation. Therefore, even if a heat treatment is implemented after the barrier metal 30A has been formed and then the bump 35 is formed on the barrier metal 30A, an oxide layer will not be formed on the surface of the fourth conductive metal layer 34 during the heat

treatment. This is advantageous since the oxide layer has a negative effect for joining the bumps. Therefore, the bump 35 can be securely joined on the barrier metal 30A, and thus the reliability of the semiconductor device 20 can be improved.

In the following, a method of manufacturing the semiconductor device 20 of the above-described structure will be described.

Although the semiconductor device 20 is manufactured through a number of steps, only those steps essential to the present invention will be described in detail. The following explanation relates to a step of forming barrier metals (barrier metal forming step), a step of forming bumps (protruded electrode forming step), and a step of testing a plurality of semiconductor chips provided on a wafer (testing step).

Figs. 4 to 9 are diagrams showing various sub-steps of the barrier metal forming step of a first embodiment of a method of manufacturing a semiconductor device of the present invention. Fig. 4 shows a part of a wafer 25 provided with the electrodes 5 and the insulating layer 6 having the openings 7 through which the electrodes 5 are exposed. It is to be noted that, as a result of other manufacturing steps, the wafer 25 has already been provided with a plurality of semiconductor chips (not shown) integrated thereon. Fig. 4 is an enlarged view showing a region at one of the electrodes 5 provided on one of the plurality of semiconductor chips formed on the wafer 25.

As shown in Fig. 5, first of all, a first conductive metal coating 41 is formed on the wafer 25 through a sputtering process. Then, a second conductive metal coating 42 is provided on the first conductive metal coating 41. In the present embodiment, the first conductive metal coating 41 may be made of titanium (Ti) and has a thickness of about

500 nm. The second conductive metal coating 42 may be made of copper (Cu) and also has a thickness of about 500 nm.

As shown in Fig. 6, after the first and second
5 conductive metal coatings 41 and 42 have been formed, a positive resist 44 is provided on the second conductive metal coating 42. Then, the positive resist 44 undergoes an etching process so as to provide openings 45 formed at positions corresponding to the
10 electrodes 5. The opening 45 is formed with an area greater than the area of the electrode 5.

Then, an electric current is applied to the first conductive metal coating 41 or the second conductive metal coating 42. Then, an electrolytic
15 plating process is carried out so as to provide the third conductive metal layer 33 on the second conductive metal coating 42 and to provide the fourth conductive metal layer 34 on third conductive metal layer 33. The third conductive metal layer 33 has a
20 thickness of about $2\text{ }\mu\text{m}$ and the fourth conductive metal layer 34 has a thickness of about $0.1\text{ }\mu\text{m}$. Fig. 7 is a diagram showing a state where the third conductive metal layer 33 and the fourth conductive metal layer 34 have been formed.

25 In the present embodiment, the third conductive metal layer 33 is made of nickel (Ni) and the fourth conductive metal layer 34 is made of gold (Au). Also, as has been described above, the fourth conductive metal layer 34 is a thin metal layer having
30 a thickness of about $0.1\text{ }\mu\text{m}$. The weight of the fourth conductive metal layer 34 is less than 2% (weight percentage) of the weight of the bump 35 to be formed in the protruded electrode forming process. The
35 weight of the fourth conductive metal layer 34 can be easily controlled by changing the current conducting time and the plating current during the electrolytic plating process.

Also, as has been described above, the opening 7 provided in the resist 44 has an area greater than that of the electrode 5 (e.g., the opening has a size of $\phi 110 \mu\text{m}$). Therefore, since the resist 44 is used as a mask, the fourth conductive metal layer 34 has an area greater than the area of the electrode 5. In detail, when viewed as a plan view, a diameter of the fourth conductive metal layer 34 is substantially the same as a diameter of the bump 35. Also, since the first to fourth conductive metal layers 31 to 34 are laminated as a layered structure, the surface of the uppermost fourth conductive metal layer 34 will be substantially flat.

After the third and fourth conductive metal layers 33, 34 are formed in the opening 45, the resist 44 is removed. Then, unwanted portions of the first and second conductive metal coatings 41, 42 are removed by wet etching, so as to provide the first and second conductive layers 31, 32, respectively. Thus, the barrier metal 30A having a structure shown in Fig. 9 is formed.

In the present embodiment, after the barrier metal forming step, the wafer 25 is diced so as to be separated into individual semiconductor chips 27. Fig. 10 is a diagram showing the individualized semiconductor chip 27.

After individualizing the wafer 25 into the semiconductor chips 27, the testing step is carried out on each semiconductor chip 27. Figs. 11 to 13 are diagrams showing the testing step.

In the present embodiment, the testing step includes an electrical test and a burn-in test. Figs. 11 and 12 are diagrams showing how the electrical test is carried out on the semiconductor chip 27. First, a plurality of probes 14 connected to a tester is electrically connected to the semiconductor chip 27. The testing signals are supplied to the semiconductor

chip 27 via the probes 14. Then, based on the output signals from the semiconductor chip 27, it is determined whether the semiconductor chip 27 is good or bad.

5 As shown in Figs. 11 and 12, in the present embodiment, the probes 14 are connected to an upper part of the barrier metal 30A.

 That is to say, in the present embodiment, the test step is implemented after the barrier metal
10 forming step and before the protruded electrode forming step. Thus, at the time of implementing the testing step, the bump 35 is not yet provided on the barrier metal 30A. Therefore, the semiconductor chip
15 27 can be tested by directly connecting the probe 14 to the barrier metal 30A.

 As has been described, the fourth conductive metal layer 34 positioned at the uppermost part of the barrier metal has a comparatively great area and is substantially flat. Therefore, the probe 14 can be
20 more securely connected to the barrier metal 30A (the fourth conductive metal layer 34) as compared to the method of the related art in which the probe 14 is connected to the spherical bump 4 (see Fig. 3). Thus, the test can be implemented with an improved
25 reliability.

 Also, the fourth conductive metal layer 34 is made of a material having a good resistance to reaction and adhesion with the metal used for the probe
30 14. When the probe 14 is provided with the plated part 15, the fourth conductive metal layer 34 is made of a material having a good resistance to reaction and adhesion with the metal used for the plated part 15.

 Therefore, even if the probe 14 is connected to the fourth conductive metal layer 34 and a part of
35 the fourth conductive metal layer 34 adheres to the probe 14 (or to the plated part 15), the probe 14 and the plated part 15 will not be degraded. Thus, since

it is no longer necessary to replace expensive the probes 14 frequently, the testing cost can be reduced while increasing the reliability of the test step.

Fig. 15 is a chart showing combinations of materials of the probe 14 (or of the plated part 15, if any) and the third conductive metal layer 33, and possible materials of the fourth conductive metal layer 34. The material of the probe 14 and the material of the third conductive metal layer 33 are used as parameters for specifying the material of the fourth conductive metal layer 34. The combination of the materials of the fourth conductive metal layer 34 and the probe 14 is related to the material of the third conductive metal layer 33 which provided under the fourth conductive layer and which prevents the diffusion of the bump 35.

From Fig. 15, it can be seen that when the probe 14 (or the plated part 15) is made of palladium (Pd) and the third conductive metal layer 33 is made of nickel (Ni), a preferable material for the fourth conductive metal layer 34 is palladium (Pd) or gold (Au).

Similarly, when the probe 14 (or the plated part 15) is made of tungsten (W) and the third conductive metal layer 33 is made of palladium (Pd), a preferable material for the fourth conductive metal layer 34 is selected from a group consisting of gold (Au), silver (Ag), platinum (Pt) and rhodium (Rd).

Now, Fig. 13 is a diagram showing how the burn-in test, which is a type of a reliability test, is carried out on the semiconductor chip 27. As shown in Fig. 13, the semiconductor chip 27 is mounted on a testing card 50 and then placed in a burn-in chamber 52. Then, a heating process and a cooling process are alternately repeated. Thus, the semiconductor chips which may cause a failure due to inherent weakness or manufacturing variation will be removed. Therefore,

the burn-in test may be considered as a type of a screening test.

In the present embodiment, a burn-in test at 125 °C for 48 hours is repeated twice. The test card 5 50 is provided with test terminals 51, such as stud bumps, and the test terminals 51 are respectively connected to the barrier metals 30A of the semiconductor chip 27.

With the testing step of the present 10 embodiment in which the test terminals 51 are brought in contact with the barrier metals 30A, when the above-described burn-in test is implemented, an oxide layer may be produced at the surface of the fourth conductive metal layer 34. Accordingly, there is a 15 risk that the joining property between the bumps 35 and the barrier metals 30A may be degraded.

However, in the present embodiment, since the fourth conductive metal layer 34 is made of a material having resistance to oxidization. Therefore, 20 even if the heating process is carried out in the testing step, the oxide layer will not be formed on the surface of the fourth conductive metal layer 34. Accordingly, in the protruded electrode forming step (described later), the bump 35 can be securely joined 25 on the barrier metal 30A (the fourth conductive metal layer 34).

After the testing step described above, the protruded electrode forming step is carried out. Solder balls of solder having a Pb/Sn ratio of 95%/5% 30 are transferred onto the barrier metal 30A. Then, a reflow process is carried out under at 350 °C under nitrogen atmosphere. Thereby, the bump 35 having a height of about 100 μm are formed. Subsequently, processes such as cleaning the flux are implemented. 35 Thus, the semiconductor device 20 shown in Fig. 14 is manufactured.

In the protruded electrode forming step, the

reflow process (heat treatment) is implemented.
However, since the fourth conductive metal layer 34
is made of a material which can be easily alloyed with
the bump 35, there is a risk that the fourth conductive
5 metal layer 34 dissolves and alloys with the bump 35.

However, in the present embodiment, the
weight of the fourth conductive metal layer 34 is less
than 2% (weight percentage) of the weight of the bump
35. Therefore, even if the fourth conductive metal
10 layer 34 is entirely alloyed with the bump 35, the
amount of the fourth conductive metal layer 34 in the
bump 35 is considerably small. Thus, the degradation
of the bump 35 can be prevented.

The fourth conductive metal layer 34 may be
15 made of a material which can be easily alloyed with
the bump 35 so as to improve the electrical connectivity
and prevent the degradation of the probe 14 in the
testing step. However, as has been described above,
the joining force between the bumps 35 and the barrier
20 metals 30A can be maintained due to low amount of the
fourth conductive layer 34. Thus, the bumps 35 will
not fall off when mounted on the semiconductor device
20, and the mounting reliability of the semiconductor
device 20 can be improved.

25 Figs. 16 to 19 are diagrams showing various
barrier metal forming steps of a second embodiment of
a method of manufacturing a semiconductor device of
the present invention. In Figs. 16 to 19, same elements
as those shown in Figs. 4 to 14 are illustrated with
30 same reference numerals.

The present embodiment is characterized in
that the barrier metal does not include the third
conductive metal layer 33 of the first embodiment. In
other words, the intermediate conductive layer must
35 include one of nickel (Ni) and palladium (Pd), since
those material have high diffusion protection property.
However, depending on materials of other stacked

layers, the intermediate conductive layer need not contain copper (Cu) which has a low diffusion protection property.

Therefore, in the present invention, the
5 first conductive metal layer 31 is made of a material such as titanium (Ti). The second conductive metal layer 32 is made of a material such as nickel (Ni) or palladium (Pd). The fourth conductive metal layer 34 is made of a material such as gold (Au). In the present
10 embodiment, the fourth conductive metal layer 34 is directly laminated on the second conductive metal layer 32.

In order to manufacture the barrier metal of the present embodiment, first of all, the first and
15 second conductive metal coatings 41, 42 are formed as shown in Fig. 16. Then, the resist 44 having openings 45 are formed on the second conductive metal coating 42. Then, as shown in Fig. 17, the fourth conductive metal layer 34 is directly formed on the second
20 conductive metal coating 42. Subsequently, as shown in Fig. 18, the resist 44 is removed. Thereafter, the unwanted parts of the first and second conductive metal coatings 41 and 42 are removed by etching, so as to provide the first and second conductive layers 31, 32,
25 respectively. Thus, the barrier metal 30B having a triple-layered structure shown in Fig. 19 is formed.

It can be understood that the number of layers of the barrier metal can be altered by appropriately selecting the material of each conductive metal layer.
30 Therefore, the structure of the barrier metal is not limited to the four-layered structure of the first embodiment or to the triple-layered structure of the second embodiment, but can be a layered structure having five or more conductive metal layers. Even with
35 the layered structure having five or more conductive metal layers, if a material of the uppermost conductive metal layer is selected to have an appropriate property

with the material of the bump (protruded electrode), the testing step can be implemented before the protruded electrode forming step.

In the above-described embodiment, first,
5 the barrier metal forming step is implemented. Subsequently, the wafer 25 is diced so as to obtain individualized semiconductor chips 27. Therefore, in the above-described embodiment, the testing step and the protruded electrode forming step are implemented
10 on the individualized semiconductor chips 27.

However, it is inefficient to implement the testing step and the protruded electrode forming step on each one of the individualized semiconductor chips 27. Thus, dicing can be implemented not immediately
15 after the barrier metal forming step. Instead, the testing step and the protruded electrode forming step can be implemented after the barrier metal forming step. The wafer 25 can be diced thereafter.

In this manner, the testing step and the
20 protruded electrode forming step can be simultaneously implemented on the plurality of semiconductor chips 27 formed on the wafer 25. Thereby, the manufacturing efficiency of the semiconductor devices can be improved.

Also, the protruded electrode forming step
25 is implemented only on those semiconductor devices which have been determined as good semiconductor devices during the testing step. Thus, the bumps 35 will not be formed on bad semiconductor devices, so
30 that a wasteful use of bump material can be avoided.

Also, the above-described steps of
selectively forming the bumps 35 may be carried out in various transferring method where the bumps 35 are transferred to the individualized semiconductor chip
35 27. Also, when the bumps 35 are formed on an undiced wafer, if bump forming method such as metal jet method is employed, the bumps 35 may be only formed on good

semiconductor chips based on the location data of bad semiconductor chips. With the metal jet method, the solder is expelled onto the wafer 25 in a similar to ink jet method, so as to form the bumps.

5 Further, the present invention is not limited to these embodiments, but variations and modifications may be made without departing from the scope of the present invention.

The present application is based on Japanese
10 priority application No. 11-118543 filed on April 26,
1999, the entire contents of which are hereby
incorporated by reference.

[illegible]

WHAT IS CLAIMED IS:

5

1. A method of manufacturing a semiconductor device provided with first electrodes formed on a semiconductor substrate and second protruded electrodes provided on said first electrodes, respectively, said method comprising the steps of:

10

a) forming a barrier metal on each one of said plurality of first electrodes, said step a) further comprising the sub-steps of:

15

- laminating a lowermost conductive metal layer on said first electrode, said lowermost conductive metal layer having a comparatively good joining property with said first electrode;

20

- laminating an intermediate conductive metal layer on said lowermost conductive metal layer; and

25

- laminating an uppermost conductive metal layer on said intermediate conductive metal layer, said uppermost conductive metal layer serving as a barrier layer for preventing said second protruded electrode from being diffused in said first electrode;

30

b) forming said second protruded electrodes on said barrier metals; and

c) implementing one or more predetermined test on said semiconductor substrate by applying signals to said semiconductor substrate,

wherein said step c) is carried out after said step a) and before said step b).

35

2. The method as claimed in claim 1, wherein,

in said step c), the signals are supplied to the semiconductor substrate by contacting said barrier metals with probes.

5

3. The method as claimed in claim 1, wherein said uppermost conductive metal layer is made of a material having resistance to reaction and adhesion with the metal used for the probe.

15

4. The method as claimed in claim 1, wherein said uppermost conductive metal layer is made of a material which can be easily alloyed with the material of the protruded electrode and has resistance to oxidation.

25

5. The method as claimed in claim 1, wherein said step b) is implemented only on those semiconductor chips which have been determined as good semiconductor chips during said step c).

30

6. The method as claimed in claim 1, said step b) further comprising the sub-steps of:

35 - forming a first metal coating, which will become said lowermost conductive metal layer, on substantially the entire surface on said semiconductor

5

20 9. The method as claimed in claim 6, wherein
said second conductive metal layer is made of a metal
chosen from a group consisting of copper (Cu), nickel
(Ni) and palladium (Pd), or of an alloy containing a
metal chosen from a group consisting of copper (Cu),
25 nickel (Ni) and palladium (Pd).

10. The method as claimed in claim 6, wherein
said third conductive metal layer is made of a metal
chosen from a group consisting of copper (Cu), nickel
(Ni) and palladium (Pd), or of an alloy containing a
metal chosen from a group consisting of copper (Cu),
nickel (Ni) and palladium (Pd).

11. The method as claimed in claim 6, wherein
said fourth conductive metal layer is made of a metal
5 chosen from a group consisting of gold (Au), platinum
(Pt), palladium (Pd), silver (Ag) and rhodium (Rh) or
of an alloy containing a metal chosen from a group
consisting of gold (Au), platinum (Pt), palladium (Pd),
silver (Ag) and rhodium (Rh).

10

12. The method as claimed in claim 6, wherein
15 said protruded electrode is made of a metal chosen from
a group consisting of tin (Sn), lead (Pb), silver (Ag),
indium (In) and bismuth (Bi) or of an alloy containing
a metal chosen from a group consisting of tin (Sn),
lead (Pb), silver (Ag), indium (In) and bismuth (Bi).

20

13. A semiconductor device having a
25 semiconductor chip, first electrodes formed on said
semiconductor chip, barrier metals formed on said
first electrodes and having laminated structures, a
plurality of second protruded electrodes, which serves
as external connection terminals, formed on said
30 barrier metals,

said barrier metal comprising:

a lowermost conductive metal layer laminated
on said first electrodes and made of one or more
conductive metal coating having a comparatively good
35 joining property with said first electrodes;
an intermediate conductive metal layer
laminated on said lowermost conductive metal layer and

made of one or more conductive metal layer having a comparatively good joining property with said lowermost conductive metal layer, at least one of said conductive metal layers serving as a barrier layer for preventing said protruded electrodes from diffused into said conductive metal layers; and

an uppermost conductive metal layer laminated on said intermediate conductive metal layers and made of one or more uppermost conductive metal layers made of a material which easily alloys with the material of said plurality of the uppermost conductive metal layers.

15

14. A method of manufacturing a semiconductor device comprising the steps of:

a) forming barrier metals on first electrodes provided on a chip of the semiconductor device;

b) implementing, after said step a), a predetermined test on the semiconductor device by applying a signal to the semiconductor device via at least one of the barrier metals; and

c) forming, after said step a), second protruded electrodes on the barrier metals.

30

15. The method as claimed in claim 14 wherein said step a) comprises a step of forming the barrier metals each having a multilayer structure having uppermost conductive metal layer which is made of a material which can be alloyed with a material of the second protruded electrodes and has a resistance to

reaction and adhesion with a material of probes used for said step b) and with a material of plated parts provided on the probes.

A method of manufacturing a semiconductor device includes the steps of forming barrier metals on first electrodes provided on a chip of the semiconductor device, implementing a predetermined test on the semiconductor device by applying a signal to the semiconductor device via at least one of the barrier metals, and forming second protruded electrodes on the barrier metals. The predetermined tests are implemented before forming second protruded electrodes on the barrier metals.

5
10

FIG.1 PRIOR ART

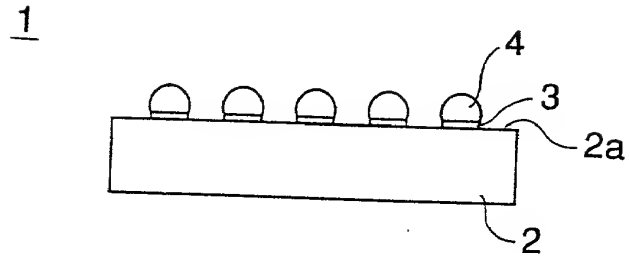


FIG.2 PRIOR ART

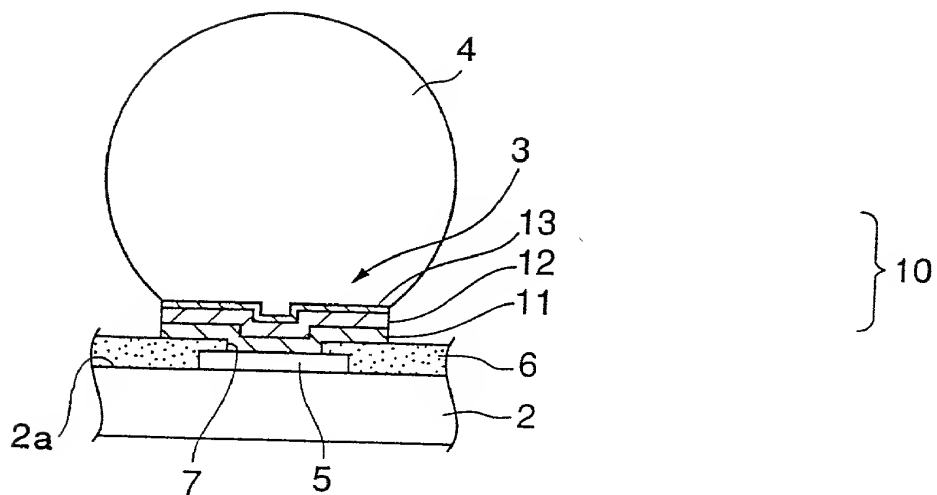


FIG.3 PRIOR ART

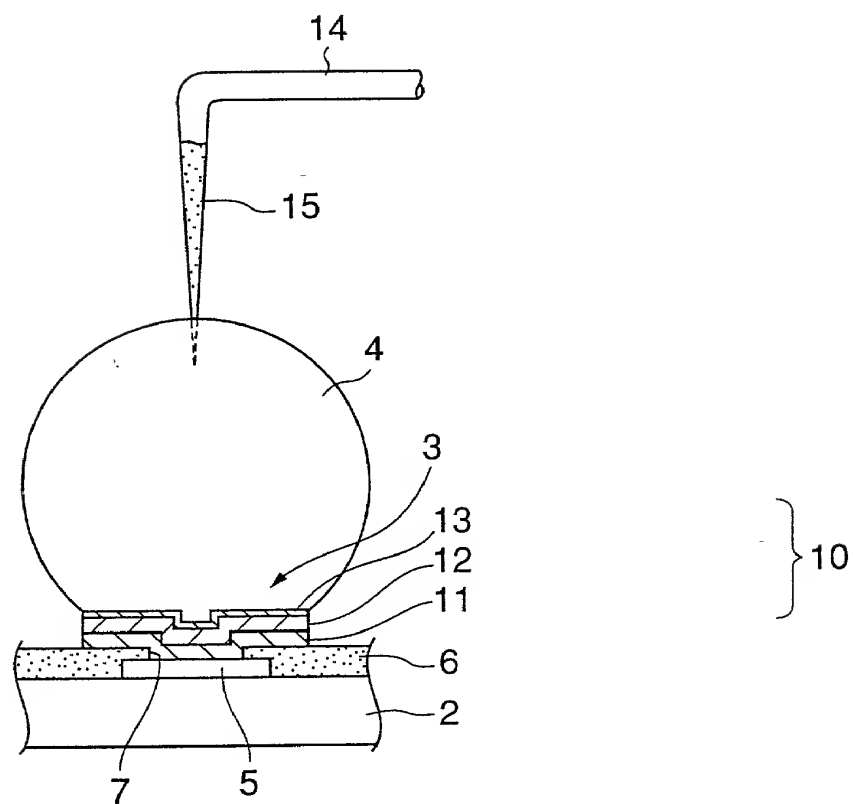


FIG.4

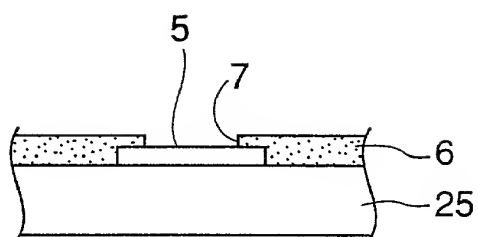


FIG.5

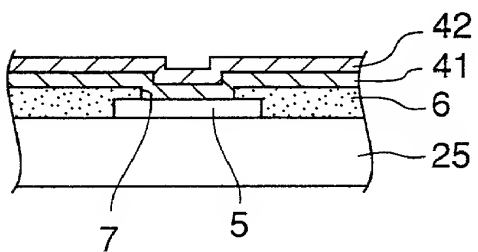


FIG.6

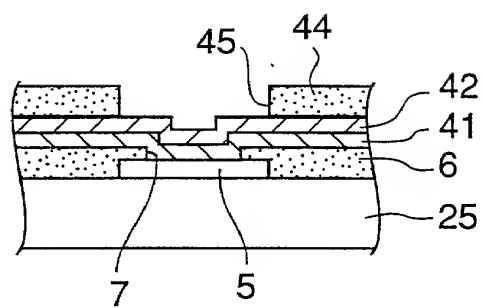


FIG.7

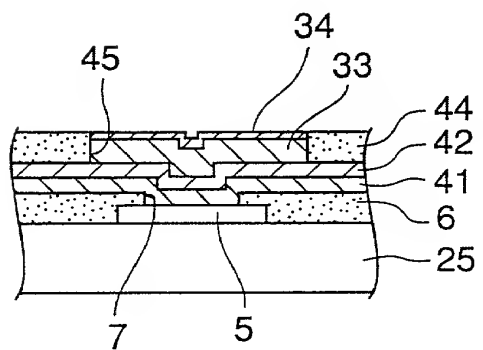


FIG.8

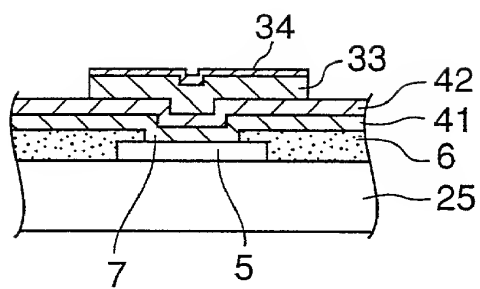


FIG.9

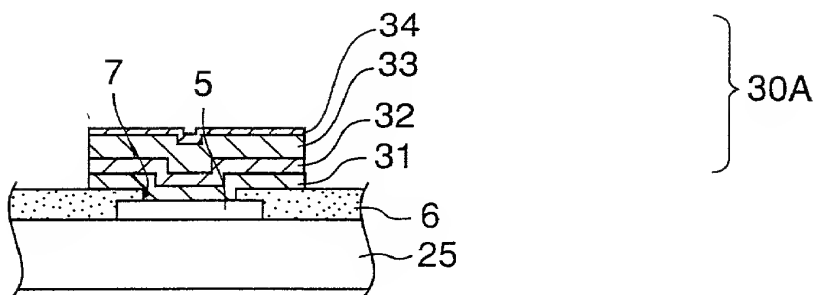


FIG.10

27

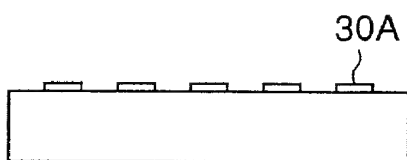


FIG.11

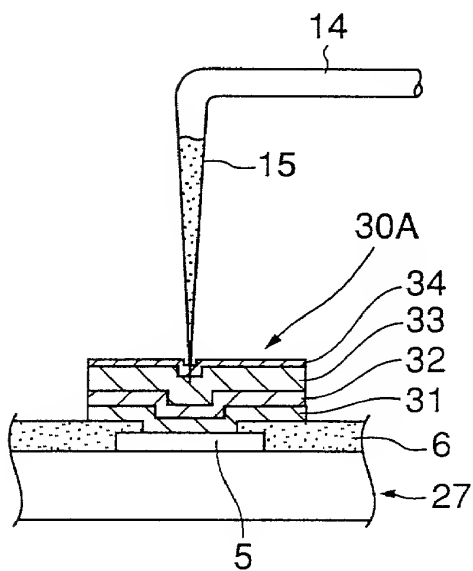


FIG.12

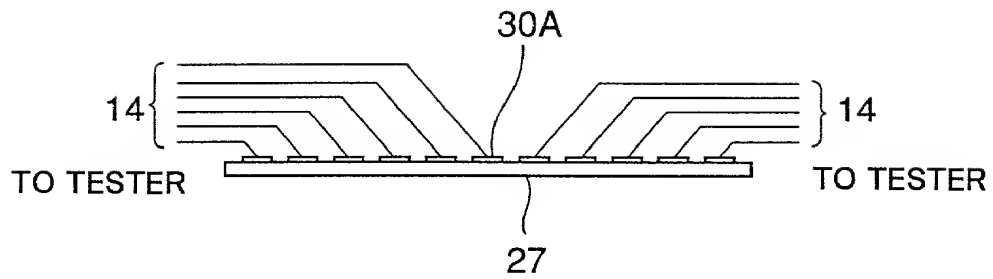


FIG.13

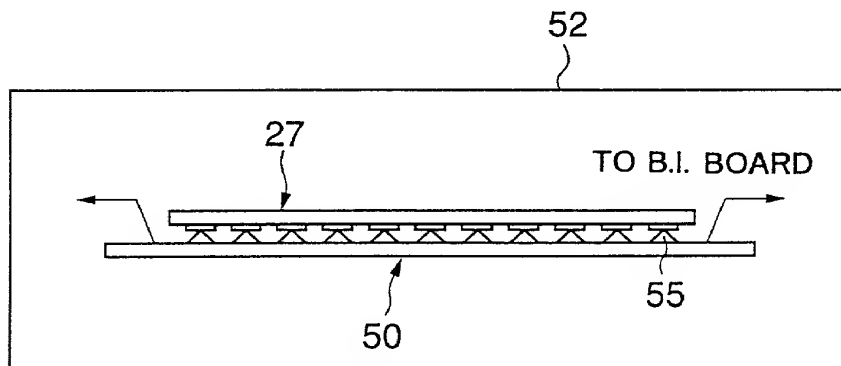
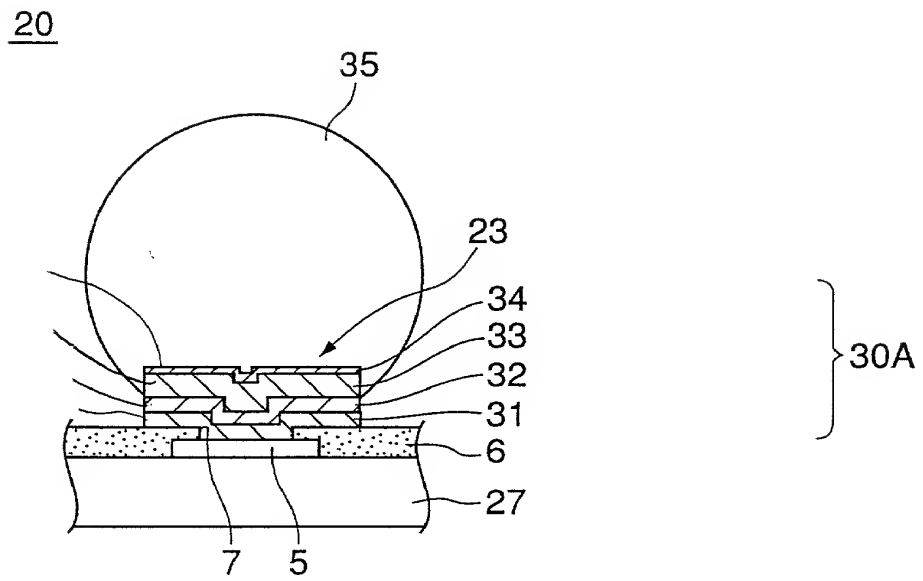


FIG.14



	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2
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		METERIAL OF PROBE		
		Au	Pd	W
THIRD CONDUCTIVE MERTAL LAYER	Cu	Au	Pd Au	Au Ag Pt Rh Pd
	Ni	Au	Pd Au	Au Ag Pt Rh Pd
	Pd	Au	Au Ag Pt Rh	Au Ag Pt Rh

FIG.16

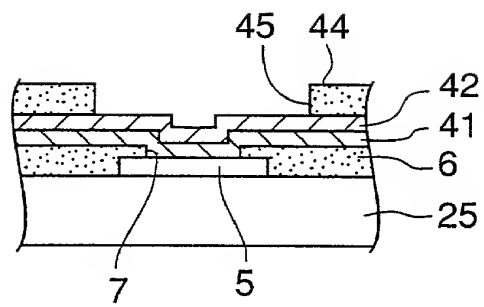


FIG.17

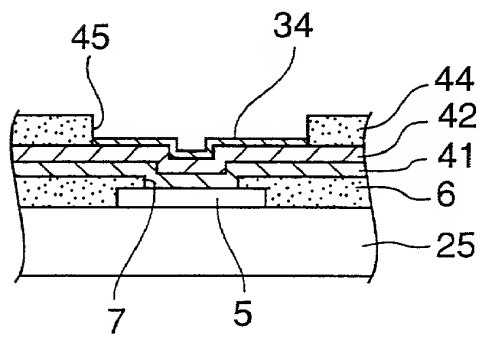


FIG.18

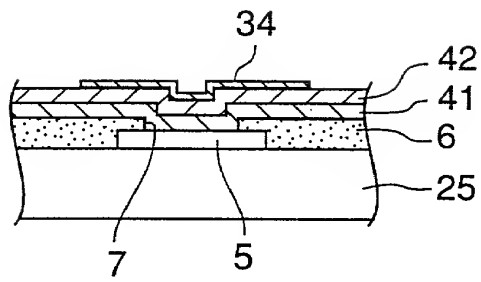
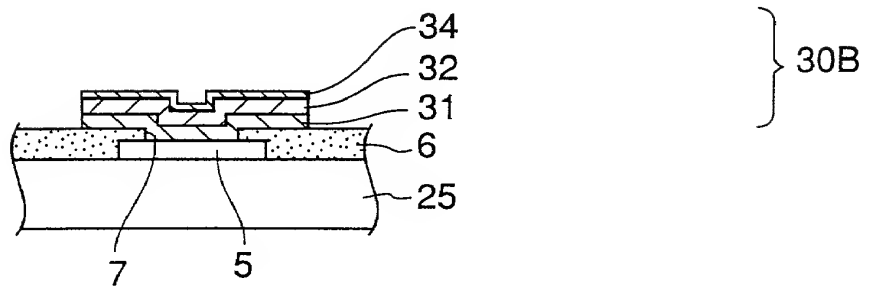


FIG.19



Declaration and Power of Attorney for U.S. Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that:

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

SEMICONDUCTOR DEVICE AND METHOD OFMANUFACTURING THE SAME

上記発明の明細書（下記の欄でx印がついていない場合は、本書に添付）は、

the specification of which is attached hereto unless the following box is checked:

☐ __月__日に提出され、米国出願番号または特許協定条約国際出願番号を_____とし、
（該当する場合）_____に訂正されました。☐ was filed on _____
as United States Application Number or
PCT International Application Number
_____ and was amended on
_____ (if applicable).

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第37編第1条56項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

Japanese Language Declaration (日本語宣言書)

私は、米国法典第35編119条(a)-(d)項又は365条(b)項に基づき下記の、米国外の国の少なくとも一カ国を指定している特許協力条約365(a)項に基づき国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

Prior Foreign Application(s)

外国での先行出願 Pat. Appln. No. 11-118543	Japan
(Number) (番号)	(Country) (国名)
(Number) (番号)	(Country) (国名)

私と、第35編米国法典119条(e)項に基づいて下記の米国外の特許出願規定に記載された権利をここに主張いたします。

(Application No.) (出願番号)	(Filing Date) (出願日)
-----------------------------	------------------------

私は、下記の米国法典第35編120条に基づいて下記の米国外の特許出願に記載された権利、又は米国外を指定している特許協力条約365条(c)に基づき権利をここに主張します。また、本出願の各請求範囲の内容が米国法典第35編112条第1項又は特許協力条約で規定された方法で先行する米国外の特許出願に開示されていない限り、その先行米国外出願書提出日より本出願書の日本国内または特許協力条約国際提出日よりの期間中に入手された、連邦規則法典第37編1条56項で定義された特許資格の有無に関する重要な情報について開示義務があることを認識しています。

(Application No.) (出願番号)	(Filing Date) (出願日)
-----------------------------	------------------------

(Application No.) (出願番号)	(Filing Date) (出願日)
-----------------------------	------------------------

私は、私自身の知識に基づいて本宣言書中で私が行なう表明が真実であり、かつ私の入手した情報と私の信じていることに基づき表明が全て真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行為は米国法典第18編第1001条に基づき、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような故意による虚偽の表明を行えば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごとく宣誓を致します。

I hereby claim foreign priority under Title 35, United States Code, Section 119 (a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Priority Not Claimed
優先権主張なし

26/April/1999	<input type="checkbox"/>
(Day/Month/Year Filed) (出願年月日)	
(Day/Month/Year Filed) (出願年月日)	<input type="checkbox"/>

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.) (出願番号)	(Filing Date) (出願日)
-----------------------------	------------------------

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of application.

(Status: Patented, Pending, Abandoned) (現況: 特許許可済、係属中、放棄済)

(Status: Patented, Pending, Abandoned) (現況: 特許許可済、係属中、放棄済)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Japanese Language Declaration (日本語宣言書)

委任状： 私は下記の発明者として、本出願に関する一切の手続きを米特許商標局に対して遂行する弁理士または代理人として、下記の者を指名いたします。(弁護士、または代理人の氏名及び登録番号を明記のこと)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith (list name and registration number)
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